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Validation and analysis of the Enhanced Naval Warfare Gaming System release 2 cruise missile model

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VALIDATION AND ANALYSIS
OF THE
ENHANCED NAVAL WARFARE GAMING SYSTEM
RELEASE 2
CRUISE MISSILE MODEL

by

David F. Cashin

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This thesis is an analysis of the cruise missile targeting and engagement models in the Enhanced Naval Warfare Gaming System (ENWGS) release 2. Flow charts derived directly from the computer code are included. The purpose of this thesis is to analyze the computer code to determine its realism in modeling actual cruise missile engagements and to provide the ENWGS users with insight to the factors affecting cruise missile engagements in the game. Modifications to the Enhanced Naval Warfare Gaming System are proposed. Recommendations are also included for Game Directors using the game.

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Validation and Analysis of the Enhanced Naval Warfare Gaming System release 2 Cruise Missile Model

by

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requirements for the degree of

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September 1989

ABSTRACT

This thesis is an analysis of the cruise missile targeting and engagement models in the Enhanced Naval Warfare Gaming System (ENWGS) release 2. Flow charts derived directly from the computer code are included. The purpose of this thesis is to analyze the computer code to determine its realism in modeling actual cruise missile engagements and to provide the ENWGS users with insight to the factors affecting cruise missile engagements in the game. Modifications to the Enhanced Naval Warfare Gaming System are proposed. Recommendations are also included for Game Directors using the game.

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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to provide a detailed analysis of the cruise missile targeting and engagement models used in the Enhanced Naval Warfare Gaming System (ENWGS) release 2. Included in this thesis are recommendations for the improvement of the computer models. Information is also provided concerning which factors most strongly affect the outcome of cruise missile engagements in the game. This type of analysis is necessary to ensure that the Navy receives a finished product which is a realistic and useful simulation of naval warfare. It will also provide users with a better understanding of the interactions which take place in the game. This will allow game directors to provide better training, and will ensure that game players will have no misconceptions about how the game operates.

B. ENHANCED NAVAL WARFARE GAMING SYSTEM OVERVIEW

The Enhanced Naval Warfare Gaming System is an enhanced version of the Naval Warfare Gaming System developed by Computer Sciences Corporation of Moorestown, New Jersey under U.S. Navy Contract. The Naval Warfare Gaming System was first installed in 1982 at the Center for War Gaming at the Naval War College in Newport, Rhode Island. ENWGS release 1 was accepted by the Navy and installed in August of 1986. The second release of ENWGS was begun in July of 1987 to enhance the realism of the air operations model, improve the user interface, and refine the sensor models. Currently the ENWGS release 1 is in operation at the Center for War Gaming at the Naval War College. Release 2 is in operation at Tactical Training Group Atlantic Dam Neck, Virginia, and at Tactical Training Group Pacific San Diego, California, with remote stations at the Naval Postgraduate School Monterey, California, Commander in Chief Pacific Fleet Honolulu, Hawaii, Commander in Chief Atlantic Fleet Norfolk, Virginia, and at Commander in Chief United States Naval Forces Europe London, UK.

The use of gaming as a supplement to fleet exercises has become increasingly important as the expense of operating fleet units has risen. The use of computers as a gaming tool has become essential because of the complexity of modern naval warfare and the need to conduct training in a real time environment.

The ENWGS System Specification [Ref. 1: p. 3] gives the following description of the ENWGS.

> The Enhanced Naval Warfare Gaming System (ENWGS) is designated to be a geographically distributed war gaming system capable of supporting the needs and objectives of CNO, Fleet Commanders, Naval War College (NWC) , and Tactical Training Groups (TACTRAGRU's). As the Navy's war gaming system, ENWGS shall provide a detailed, realistic computer simulation of the naval warfare environment. The System will use common hardware and software to support interactive gaming via a local and long distance communication network.

The ENWGS System Specification [Ref. 1: p. 4] also states that the mission of the game system is:

> As an operational and educational tool, ENWGS will focus on strategic tactical war gaming and decision making, doctrine and tactics development/evaluation, operational planning/evaluation, training curriculum support and improvement of war gaming methodologies.

C. PROCEDURE

The organization of the thesis will follow the chronology of a cruise missile attack as it is approximated by the ENWGS model. Chapter 2 will discuss the air-to-surface weapons targeting subroutine (M19) which determines how cruise missiles and other air-to-surface weapons are assigned specific targets in their acquisition areas. Chapter 3 will discuss the cruise missile hit determination subroutine (M22) and the electronic countermeasures subroutine (M30) which determines if cruise missiles strike their assigned targets. Flow charts of these subroutines are provided in Appendix A. Chapter 4 will cover conclusions about the weakness's of the model as a representation of a real cruise missile engagement. Chapter 5 comprises recommendations for the improvement of the models. In addition to recommended changes to the computer models, specific recommendations for Game Directors and Data Base Managers on how to improve the realism of the game are made.

D. DEFINITIONS

When an air, surface, or subsurface platform is given a take order the following definition applies to a missile strike: A missile strike or track is a group of missiles launched by a single platform in one salvo. Each group of missiles in a single track symbol is run through the subroutines. So if there is only one missile in the track, that one missile looks at the target area, is assigned to a target, and has a hit probability generated. If ten missiles were launched by a platform at the same time and at the same target the entire salvo would be represented by one missile track symbol. When this

track arrives in the target area, the salvo of missiles has a single field of view, the ten missiles are assigned to targets in the zone, and a single hit probability is generated for the entire salvo. A different procedure is used for scheduled airborne raids. An airborne strike is generated by an airplan and is treated as a whole. When the airborne strike arrives in the target area, each aircraft is assigned a target in the target zone for the strike. Then each aircraft fires all of its missiles at its assigned target.

II. CRUISE MISSILE TARGETING (M19)

A. OVERVIEW

This cruise missile targeting routine is called by the missile monitoring routine (M18) when the cruise missiles enter the final portion of their flight path at seeker turn-on. The strike is identified as a subsurface/surface launched missile strike or an aircraft launched strike. Targets and missiles are sorted into groups of anti-radiation homing missiles (ARM) and non-ARM targets and missiles. The seeker field of view is calculated, then the routine determines which ships are in the target zone. The targeting quality value determines how the ships are to be weighted in the target zone. The missiles are assigned stochastically or deterministically among the target ships. ARM missiles are assigned only to ARM targets and non-ARM missiles are apportioned amongst all targets.

B. ENGAGEMENT AND STRIKE ORDERS

Cruise missile attacks conducted by air, surface, and subsurface platforms can be initiated by using an engagement order. Using the engagement order the player designates a target by track name, or by latitude and longitude. Salvo size is selected, and in the case of surface and subsurface launched attacks, the engagement can be designated as a bearing-only launch, a launch with waypoints, or the launch platform is assigned a time-on-top. A bearing-only launch indicates that as soon as the missile is launched its seeker is turned on and the missile searches along the assigned bearing until it finds a target. Waypoints are designated points along a flight path which the missile must pass through on its way to the target. When a platform is assigned a time-on-top, the platform is being ordered to launch its missiles so that they arrive in the target area at the specified time. Therefore, the platform must calculate when to launch its cruise missiles so that given the speed of the missile and the range to the target, the missiles hit the target at the ordered time.

Aircraft may be ordered to attack a target by forming a strike on the airplan. The type, number, and weapons load of each aircraft is defined in the airplan. Additionally the target is designated by name, or a position is indicated as the aim of the strike. Both air strikes and salvos of cruise missiles are given a strike name so that the Game Director knows an attack has been conducted and may alter the parameters affecting the strike if necessary. These parameters are: targeting quality, target zone center, target zone radius, and crossover range. Target zone center and target zone radius are self-

explanatory. Targeting quality reflects the quality of the targeting information that the attacker possesses and affects how targets are weighted. Crossover range is the distance between the missile track and the target at the closest point of approach. It determines the amount of time available for a ship's self-defense weapons to react.

C. SUBROUTINE M19

1. Determining the size of the Target Zone

Once subroutine M18 has called the targeting routine, the first step is to call the appropriate missile and target data. The next step is to determine the size of the target zone. The target zone is a circle centered on the latitude and longitude, or the target track designated in the strike plan or the engagement order. Target zone radius is set by the Game Director or it is determined by calculating the radius of a circle which is defined by a missile's distance from the target and a predesignated arc. The arc is a constant written into the PL/I subroutine, which cannot be changed by the Game Director or the players. For all missiles the target zone radius is determined by the target distance from the missile at seeker turn-on multiplied by the tangent of the predesignated arc. See figures 1 and 2 in appendix A for a more detailed description of how the target zone is calculated. For surface and subsurface launched bearing-only targeted missiles, seeker turn-on is at the time of missile launch. For range and bearing launched missiles seeker turn-on is derived from the missile's data base. For airborne launched missiles, seeker turn-on occurs at the time of missile launch. The calculated radius of the zone is compared to the radius of the zone set for the strike by the Game Director, and the lesser of the two values is used. Additionally there is a check to ensure that the radius is not less than 0.5 nautical miles. Once the target zone radius is determined all ships on the surface inside the circle are designated as targets.

Target ships are now are specified as ARM targets, non-ARM targets, or both. All ships are non-ARM targets. Ships emitting the electromagnetic frequency to which the ARM's are set to home, are designated as ARM targets. The subroutine checks the frequency to which the missiles are set and all targets emitting that frequency are identified as ARM targets. The internal procedure target_weight is then called to assign target weights for assignment of missiles. The criteria for target weighting is determined by the targeting quality value set by the Game Director.

2. Targeting Quality and Procedure Target_Weight

The missiles must now be assigned to targets. This is done by the procedure target_weight in subroutine M19. Refer to figure 3 in appendix A during the following

discussion. The weighting of the ships in the target zone is determined by the targeting quality value assigned to the strike. This is a number between zero and one. Targeting quality is a number which indicates the scope and accuracy of the information held by the attacker concerning the target platform. Zero indicates that the attacker has no information on the target platform. A value of one indicates that the attacker has perfect information on the target area. Targeting quality is set by the Game Director. If it has not been set, the default value is 0.5. First, all targets are assigned a weight for all non-ARM missiles. If the targeting quality is < 0.2, (very poor), all platforms are assigned a target weight of one. If the targeting quality is between 0.2 and 0.5 targets are weighted by their radar cross-sections. If the targeting quality is > 0.5 then targets are weighted by their target value which comes from the data base. Target value is highest for aircraft carriers and battleships, and lowest for frigates and other small combatants. See ENWGS vol. 6 [Ref. 2 pp. 9-7]. Ships which were designated as the target for the strike or engagement are assigned a target weight equal to their calculated target weight which is increased by a preset multiple, regardless of the preset targeting quality. This increases the weight of the ship which is the objective of the attack.

The next step is to assign an ARM weight to the ARM targets. If the targeting quality is ≤ 0.5, the ships are given an ARM target weight of one. If the targeting quality is > 0.5 the target weight is set to the ship's target value. Again ships which were designated as the target for the strike or engagement have their target weight increased by a preset multiple. Once the targets have been weighted the missiles are assigned stochastically or deterministically to targets. The game is placed in a stochastic or deterministic mode by the Game Director prior to the start of game play.

3. Missile assignment

Missile assignment is performed in the same way for ARM and non-ARM cruise missiles. See figure 4 in appendix A during the following discussion. If the gaming is being done in the deterministic mode missile assignment is as follows: A check is performed to find if all the missiles in the strike have been assigned to targets. If all missiles have not been assigned, a target ship is drawn. The variable Ratio is set equal to the ships target weight divided by the total target weight of all of the targets. The number of missiles assigned to that ship is equal to the ratio multiplied by the number of missiles in the strike. So the number of missiles assigned to each target ship is proportional to the target ship's weight. In the case of an airborne strike the missiles are not assigned to targets, rather each aircraft is assigned to attack a single target. If the number of cruise missiles or aircraft assigned to attack a target is greater than zero, that quantity

is added to the variable Sum. When the last target platform is being assigned missiles, a check is performed to verify that the number of missiles calculated to be assigned to the target does not exceed the number of remaining unassigned missiles. If the calculated number of missiles assigned is greater than the number of missiles remaining in the track, all of the remaining unassigned missiles are assigned to the target instead. Now the procedure checks again for unassigned missiles. If the number of assigned missiles is equal to the number of missiles in the track the procedure checks to find if the variable Sum is less than the number of missiles in the track. If it is the remaining missiles are assigned one to a target until all missiles have been assigned. This is how missiles are assigned in the deterministic mode.

In the stochastic mode missiles are assigned more randomly. Refer to figure 5 in appendix A. The variable Ratio is set equal to the ratio of the target's weight to the entire weight of all of the targets. There is also an array called INT. This array is indexed for each target. As target i is drawn, the value of INT(i) is set equal to INT(i-1) plus Ratio. The procedure now loops through all of the missiles. A random number is generated from the uniform distribution between zero and one. If the value falls between INT(i) and INT(i-1) the missile is assigned to target i. Then the procedure steps to the next missile. Once all of the missiles have been tested the procedure goes to the next target until all of the missiles have been assigned. It is possible that all missiles could be assigned to a single target. But the procedure will loop through the targets, more than once if necessary, until all missiles or aircraft are assigned.

D. ANTI-CRUISE MISSILE DEFENSES

The results of all surface to air engagements, automatic or player generated, take effect before the M22 subroutine is called to determine which missiles hit their assigned targets. Before the M22 subroutine is called, the surface to air engagement routine is called to check for any automatic engagements of inbound missile or aircraft tracks. Cruise missiles are unique weapons because once launched they are assigned a track symbol so that they may be detected and attacked like any other ship or aircraft. Automatic engagements can be performed by point defense weapons such as guns and short range surface to air missiles if the proper rules-of-engagement are set. Briefly, the number of rounds available in the weapon's magazines determines how many SAM's or bullets are fired at each inbound missile. A calculation is done to determine the probability of a hit. This hit probability is affected by launcher or gun reliability, fire control effectiveness, environment, and size and altitude of the target. The number of cruise

missiles destroyed is determined stochastically or deterministically. Once all of the surface to air engagements have taken place and the destroyed aircraft and missiles have been removed the air to surface hit determination subroutine the subroutine M22 is called. ENWGS volume 6 [Ref. 2: pp. 6-15, 6-16] describes in greater detail how surface-to-air engagements are conducted. Dennis Stowkowski's thesis [Ref. 3], though it was written in 1983 concerning the initial NWGS model, still accurately describes how surface-to-air engagements are conducted in ENWGS release 2.

E. SUMMARY

Subroutine M19 identifies all of the targets in the target zone of a specific missile track generated by an engagement order or an entire aircraft strike. Depending on the targeting quality, the missiles are assigned to targets based on all targets being equal, the targets radar cross-section or on the actual value of the target. Targets designated to be attacked are given greater weight. The missiles are assigned stochastically or deterministically to targets, ensuring that all missiles are assigned. Then the surface-to-air engagement routine is called. During the surface-to-air engagement routine a ship's weapons engage the inbound missile strike. The results of this engagement determines which missiles survive to be sent to the hit determination routine.

III. HIT DETERMINATION (M22)

A. OVERVIEW

A flow diagram of this procedure is in figure 6 and figure 7 in appendix A. The purpose of subroutine M22 is to determine if a cruise missile assigned to a target ship impacts that ship. The main factor in determining if a missile hits its assigned target is the probability of a hit. This probability is a value between 0.1 and 1. The hit probability is the product of eight factors. These factors are the missile effectiveness, the reliability of the missile's mid-course guidance system, the reliability of the missile's terminal guidance system, the effect of the environment (rain and cloud cover), the electromagnetic radiation emissions control (EMCON) status of the target, the probability that the seeker acquires the target, and the interaction of the cruise missile's electronic countermeasures (ECM) and electronic counter-countermeasures (ECCM) with target electronic warfare capabilities. First, the routine verifies that the designated target track is still active and that the missile track is still active. This ensures that the hit procedure is not run on a target that no longer exists and that missiles which have been shot down or destroyed do not engage their target. Then the routine calls the data on the local environment to compute the effects of the environment on the probability of the missile hitting the target. Next the routine calls M30 which computes the effects of ECM, and ECCM on the probability of the missile hitting its assigned target. The final probability of a hit is computed using weapons effectiveness, electronic warfare effects, environmental factors, probability of acquisition, and weapons reliability. The last step is to determine if a hit occurs. This is done in a deterministic or stochastic mode.

B. M22 PROCEDURE

The missile flight monitoring subroutine calls subroutine M22 when any cruise missile track is less than one nautical mile from its designated target ship. All of the data concerning target and missile attributes are called, and then a check is performed to ensure that the target track and the missile track are still active.

1. Calculation of the Environmental Factor

The first calculation in the subroutine is to determine the value of the environmental factor. If the cloud bottom is greater than 5000 feet, cloud density is set to zero; if less than 5000 feet, the cloud density value is taken from the environmental data for the area. This indicates that the cloud layer is obscuring the target. The rain density

value is also taken from the area environmental data. If both the rain and cloud density are zero, the environmental factor is set to one. This means that the environmental conditions have no effect on the probability of the missile hitting its target. If the cloud density is the greater of the two values, the weather index is set to the cloud density. If rain density is greater, the weather index is set to rain density plus three. By adding three to the rain density, the correct position on the Weather Factors Modification Menu is indexed. The weather index and missile type are taken to the weather cross reference table and a value for the environmental factor is drawn from the table. The Weather Factors Modification Table is a table of values entered by the Data Base Manager for each cruise missile type. Weather effects data is derived from intelligence sources and entered as values between zero and 100. The data is utilized as values between zero and one. An example of such a menu is found in ENWGS volume 6 [Ref. 2 : pp. 6-43 figure 6-28].

2. Subroutine M30

This procedure is called by subroutine M22 to determine the effects of ECM and ECCM on the cruise missile's probability of hit. See figure 8 in appendix A. The subroutine calls the ship data to determine if a platform in the area is attempting to jam the cruise missile seeker. It also calls the cruise missile data to determine if it is affected by jamming and if the missile has a home-on-jam capability. Chaff and decoys are ignored. In ENWGS volume 6 there are examples of how the ECM and ECCM data for cruise missiles are entered [Ref. 2 : pp. 6-45,46 figures 6-31 and 6-32].

If jamming is being conducted and the missile is susceptible to the frequency being jammed, the ECM effectiveness value is set to the ECM value entered on the Missile Characteristics Modification Menu. If the missile is not affected by the jamming, the ECM effectiveness value is set to zero. If the missile has a home-on-jam capability in the frequency range being jammed, the ECCM effectiveness value is set to the ECCM value on the Missile Characteristics Modification Menu. If the cruise missile has no home-on-jam capability the ECCM value is set to zero.

The M22 subroutine uses the equation: $(1 - ((1 - ECCM) \times ECM))$ as a multiplier to degrade the probability of a hit. This means that if no jamming is being conducted, the multiplier is one, implying no effect. But if the missile is being jammed and has ECM and ECCM values on the Missile Characteristics Menu of less than one, the probability of a hit is seriously degraded even if the missile has a home-on-jam capability. For missiles given an ECCM value of one, the jamming has no effect on the probability of a hit. The model does not take into account the fact that jamming can act as a

beacon for a cruise missile and allow it to acquire a target that might have been outside of the missile's acquisition envelope. The most serious draw back of the release 2 M30 model is that it does not take into account the effects of chaff and decoys [Ref. 4] even though this information can still be entered into the game's data base.

3. Setting the EMCON factor

The last step prior to calculating the hit probability is to set the EMCON factor. The EMCON factor shows the effect that electronic emissions control has on the hit probability. Initially the EMCON factor is set to one. If the missile is not an ARM, the EMCON factor remains one. If the missile is an ARM, a check is performed to see if the ARM seeker frequency matches any of the emitters on the target platform. If yes, the EMCON factor is set to one. If there is not a match the hit probability is degraded and the EMCON factor is set to 0.5.

4. Final Hit Probability Calculation

All the factors that effect the probability of a hit have now been calculated. Now the probability of a hit is calculated. All of the factors are values between zero and one. The probability of hit is the product of weapon effectiveness, EMCON factor, $(1 - ((1 - ECCM) \times ECM))$, Environmental factor, Probability of target acquisition, Reliability of weapon guidance system, Reliability of weapon item, and Reliability of terminal guidance system. The final step is to determine the number of hits. In the stochastic mode a random number between zero and one is drawn for each missile. If the random number is less than the probability of a hit the missile is counted as a hit. If not, it is a miss. In the deterministic mode, however, the number of hits is equal to the probability of hit × the number of missiles in the track, rounded up to the nearest integer. Therefore, if the probability of a hit is 0.6, approximately sixty percent of the missiles assigned to the track hit the target. The battle damage assessment (BDA) routine is then called to determine the damage inflicted by the cruise missile hits.

C. ANTI-RADIATION MISSILES

In this subroutine there is not a great distinction between active radar homing and anti-radiation homing missiles. The calculation for the EMCON factor is the only step in this routine that differentiates between the two missile types. This is done through the step that checks for a match between the homing frequency of the ARM and the frequencies emitted by the target platform. A match between heat seeking missiles and the target platform is not made. The Guidance Type Modification Menu [Ref. 2 : pp. 6-47] and the Ship Properties Modification Menu [Ref. 2 : pp. 9-39] do, however, allow for this

information to be entered. The final distinction between ARM and non-ARM missiles occurs in the BDA subroutine, which will not be covered in detail by this discussion. The BDA routine takes ARM's that are designated as hits and allocates the damage amongst the target's radars and sensors on the upper levels of the target's superstructure. For a more complete disscusion of the BDA routine see ENWGS volume 6 [Ref. 2 : pp. 9-1 through 9-6] and the thesis by Knott [Ref. 5].

D. SUMMARY

The hit probability is the product of eight separate factors which degrade or have no effect on the hit probability. The effects of weapon system reliability, environment, and electronic warfare all contribute to the probability of a hit occurring. There are three areas of weakness in this model. Chaff and decoys are not modeled, IR homing missiles are treated the same as non-ARM missiles, and home-on-jam capabilities are not accurately modeled. The strength of this model is that all of the factors affecting missile performance are addressed.

IV. CONCLUSIONS

A. TARGETING ROUTINE WEAKNESS

1. Seeker patterns

The primary shortcoming of subroutine M19 is that this targeting routine does not replicate individual cruise missile seeker patterns. Each missile, whether it is one of the first generation missiles developed in the 1950's or one of the newest, sweeps the same number of degrees of arc. Because of this, many of the advantages and disadvantages of the various missiles are lost. The qualities retained by the missiles are their flight profile, warhead size, and the various parameters representing missile reliability and accuracy. A flight of missiles, in the real world, does not weigh the targets in their field of view and then distribute missiles between the targets. The intent of the routine is to simulate the random scattering of missiles in a salvo. Though the routine does scatter the missiles, it does not scatter them randomly. As in the real world, the number of missiles which acquire any given target is driven by the distance between the units in the formation. Often the distance between ships is great enough that a missile flight's target zone radius covers only one target track. However, when ships are in close formation and the inbound flight of missiles has a large seeker field of view, the attack is diluted by the missile assignment routine parceling out the missiles to different tracks. Assigning missiles by weighting is good from a tactical standpoint because all targets in the zone are attacked, and the highest value target is acquired by a majority of the missiles. This also means that if the high value unit was not detected but was present in the formation, it would still be the most heavily attacked. However, the weighting scheme also defeats the capability of modern cruise missiles to identify a single target as the high value unit and concentrate only on that target. This weighting scheme was built into the targeting model because this model is used for all forms of aircraft-to-surface attacks as well as, surface cruise missile, and subsurface cruise missile attacks. Airborne attacks are adequately modeled by the routine because the Game Director sets the parameters for the target area, with the exception of target zone center which is set by the player executing the attack. In the case of airborne attacks, the level of information available concerning the target area is usually high. So, using targeting quality, missiles can be distributed realistically to heavily attack the high value targets and suppress the defenses of the other ships in the area. Suppression of the defending escorts is more critical to

aircraft survival than it is to the success of an over-the-horizon cruise missile attack. However, as more emphasis is placed on coordinated long range surface/subsurface cruise missile attacks, the inadequacy of the model's representation of surface/subsurface launched cruise missile attacks will become more apparent. The current design of the model lacks the flexibility to incorporate future generations of cruise missiles.

2. Heat Seeking Cruise Missiles

Another inadequacy of the targeting routine for cruise missiles is that infra-red homing missiles are dealt with in the same manner as active radar homing missiles. All ships are weighted by either radar cross-section, target value, or they are weighted equally. Infra-red or heat seeking missiles should weigh targets by their heat signatures and attack accordingly.

3. Seeker Field of View Radius

The following problem is a chiefly a data base problem. Seeker turn-on ranges determine the field of view radius of a missile in the present model. Though the values for seeker turn-on may be correct, the values for field of view radius determined by them are not. It is important that seeker turn-on range be set correctly because this is often the first warning that a missile is inbound. This cue also drives certain electronic warfare responses by surface ships to missile raids. However, target acquisition is driven by the radius of the seeker's field of view. As long as the two values are linked, and the arc of the seeker's radar sweep is fixed, one of these two values will be incorrect. This will result in degraded target acquisition by missiles and incorrect electronic warfare responses by target platforms.

4. Targeting Quality

The next problem in the targeting routine is the use of targeting quality. As stated in Chapter 2, targeting quality determines if targets are weighted by radar cross-section, target value, or if all targets are treated equally. Because only a few players can be placed at game consoles, the hundreds of combat information center teams, bridge watches, sonarmen, and aircrews are not present to support the officers playing the game. To some degree this lack of processed information is made up for by the targeting quality parameter. The players may have the information to target individual ships in a target formation but they do not have the Dead Reckoning Tracers and cruise missile weapons control consoles to use the information to its best advantage. The Game Director can compensate for this by adjusting targeting quality. The question arises: Using targeting quality, how does the Game Director quantify the attacker's knowledge of the target area? Does the Game Director adjust it according to the information available to

the player or by the information that the player is utilizing? Despite the Game Director's ability to affect the outcome of an attack, players have a major impact on the success of an attack. The player has all of the information available to him that real fleet operators possess, but the player does not have the same degree of control.

When targets are designated as the object of an attack their target weight is multiplied by a factor of five. Target weight is multiplied by five no matter what the targeting quality is set at. Obviously, the high value unit which is the goal of an attack should be weighted more heavily, but there is no justification given in the PL/I code or in the references for how this value was arrived at.

5. Summary

The major fault in the targeting routine is that it is designed to accommodate all forms of air-to-surface attacks. Because the targeting routine is generalized, it does not have the capability to accurately reproduce the performance of all the various seeker and search patterns used by modern cruise missiles.

B. HIT DETERMINATION ROUTINE WEAKNESS

1. Chaff and Decoys

Chaff and decoys can be deployed by players from ships and aircraft. However, chaff and decoys have no effect on cruise missiles because the subroutine does not perform a check to see if they are deployed in the target area. Therefore players are using chaff and decoys, expecting a degradation of the performance of an inbound missile raid, but seeing no effect. Chaff and decoys were modeled in the earlier releases of the game and there is no reason given why they have been omitted from this version. In the ENWGS release 1 chaff, decoys, and jamming were modeled using an OR statement. If any one was present in the target area, the missile performance would be degraded by its ECM value. There was no provision made for the interaction of jamming, chaff, and decoys. Therefore electronic warfare in the hit determination model is rudimentary and deals only with jamming.

2. ECM-ECCM values

A missile's ECM and ECCM values are the sole parameters representing the effects of electronic warfare on cruise missiles. Currently, on every cruise missile the ECM and ECCM values are identical, and every missile has the same values. Because of this there is no difference in the ECM-ECCM capabilities of old cruise missiles and new cruise missiles. There is also no difference in the capabilities of USN and Soviet cruise missiles. The major effect of this is that missiles with a home-on-jam capability

are affected by jamming in the same way as missiles which have some other ECCM capability against jamming. Therefore home-on-jam capabilities are greatly degraded or non-existent.

3. Target-Missile EW Interactions

In the present model the only interaction between the target and the missiles, aside from surface-to-air defenses, is the jamming frequency. If the jamming is in the correct frequency band, the missiles performance is degraded. Unless the Game Director intervenes and enters dummy tracks, there is no way to confuse attacking platforms and missiles with false tracks. There is no provision made for the strength of the jamming signal. Therefore for a cruise missile there is little difference between attacking a platform with a high electronic warfare capability and one with no electronic warfare capability.

4. Summary

The major weakness of the hit determination model is the way that it deals with electronic warfare. The current model simulates the adverse effects that jamming has on cruise missiles, but it does not simulate chaff and decoys. The model also fails to allow for the various ways different cruise missiles interact with different electronic warfare tactics.

V. RECOMMENDATIONS

Recommendations for the improvement of the ENWGS will be made in two sections. The first section covers how the Game Director and Data Base Manager can improve game play. The second will discuss recommended changes for the ENWGS models.

A. GAME DIRECTOR AND DATA BASE MANAGER CONTROLS

1. Seeker patterns

Seeker turn-on ranges determine the field of view radius in the present model. The field of view radius is calculated by the following formula: Radius = Seeker Turn-on range × tangent(fixed field of view arc). This formula uses the same number of degrees of arc for the field of view of all missiles. Therefore, even though the data base may contain the correct value for the missile seeker's turn-on range, the field of view which results from the calculation is not the true field of view of the missile. The Data Base Manager needs to perform the calculation for each missile and ensure that the data value entered for seeker turn-on results in the correct field of view radius. By making this correction, the targeting model will more accurately reproduce each missile's capability to acquire a target. It is acceptable to sacrifice seeker turn-on range accuracy for the accuracy of the field of view, because ships will automatically defend themselves against air-to-surface attacks. A player does not need to rely on an ESM detection of a missile seeker, to cue him to initiate the ship's anti-cruise missile defenses.

2. Targeting Quality

Game Directors desiring to affect the results of air strikes and cruise missile attacks need to review ENWGS volume 6 [Ref. refid=vol6: pp. 7-9, 7-10] which shows the menu for altering the target area characteristics. Several factors need to be considered before assigning a value for targeting quality. First, what information does the attacker have that would improve the results of the attack but that he does not have control over in the game environment? This type of information would include visual ID and ESM information held by an air strike. If the attacker had this sort, of information the Game Director could justify raising the targeting quality above the 0.5 level. This means that targets would be attacked on the basis of their true target value. The next type of information that needs to be considered is how the missile acquires a target. If the missile selects a target based on choosing the target with the largest radar cross-section, the

targeting quality should be set between 0.2 and 0.5. If the missile views all targets as equal, the targeting quality should be set to 0.2 or lower. Target values above 0.5 should not be used for surface and subsurface launched attacks unless the missile itself has some method for distinguishing between high and low value targets. Target tracks should also not be designated as a target for an attack unless it is an air launched strike. Designating a target track as the center of an attack places a disproportionate number of missiles on the designated target. In general when cruise missiles are used in the real world, the missile is ordered to a certain position. This should also be the procedure in the game. The targeting quality for anti-radiation missiles should be less than 0.5, reflecting the fact that a transmitter is a transmitter no matter what the target's identity. However, if the missile is capable of discerning the difference between one transmitter and another, then targeting quality could be increased above 0.5 or the Game Director could indicate that the player should designate the target track as the object of the engagement.

In addition to altering the targeting quality, the target zone radius can be directly altered by the Game Director. This value should only be modified for air strikes which have visual, ESM, or radar information concerning the target area. The major problem with the target zone radius is that the Game Director must ensure that the value set as a default is large enough that it will not be chosen over the missile's field of view radius. Note: The routine chooses the smaller of the two values.

Crossover range is another factor which indirectly affects missile attacks because it determines when self-defense weapons are activated to engage inbound missiles. Large values should be set for formations which have a high density of highly capable point defense weapons. This allows the target formation's point defenses more time to conduct attacks against the missile track prior to missile impact. Conversely if the targets have a poor point defense capability or if the attack is a surprise raid against a formation in total EMCON, the crossover range should be decreased to represent the slow reaction of the target tracks. Unfortunately, crossover range must be monitored for each engagement. Crossover range does not lend itself well to the use of a preset default value which would work for a general case.

3. ECM-ECCM Values

As stated in Chapter 4, the data values set for missile ECM and ECCM capabilities do not replicate the variety of missile ECM-ECCM performance. This is due mainly to the fact that all missiles are given the value 0.5 for both values. The ECM value is the degree to which a missile's performance is degraded if it had no ECCM capability. What needs to be considered is: If jamming is present, what values of ECM and ECCM together

produce an approximation of the degradation (or improvement in the case of home-on-jam capable missiles) of the missile's ability to hit its target? At present, when jamming is conducted against cruise missiles which have no home-on-jam ability, their performance is degraded by 50 percent. If the missile does have a home-on-jam capability its performance is degraded by 75 percent. The model does not take into account other countermeasures against jamming. Using the formula $(1 - ((1 - ECCM) \times ECM))$, the Data Base Manager must set realistic values for ECM which demonstrates the degradation of a missile's hit probability if jamming is present and the missile has countermeasures not including home-on-jam. ECCM values should be set for missiles with a home-on-jam mechanism, so that the formula with the ECM value entered and the ECCM value approximate the missile's hit probability in a jamming environment. Additionally if home-on-jam frequencies and jamming frequencies which degrade missile performance do not perfectly overlap, the ECM value must adequately degrade the missiles hit probability.

The final problem in electronic warfare is chaff and decoys. The only way to approximate these missiles is for the Game Director to enter dummy tracks into the target formation. Activating new platforms is not difficult. However, the Game Director must ensure that the air defense weapons on these tracks are turned off. It may be worthwhile to design special dummy ships that have no weapon capabilities prior to the play of the game, so that the Game Director and the game controllers are not overtaxed during game play.

Operational deception can also be done in this way. Frigates could have their radar cross-sections increased to represent blip enhancing equipment.

4. Summary of Game Director actions

Although the game models do not replicate the real world exactly, there is much that can be done by adjusting weapon and platform capabilities so that realistic results can be produced. Seeker turn-on ranges and ECM-ECCM parameters need to be set to proper values. The seeker turn-on ranges could be calculated in a relatively short amount of time. ECM-ECCM values, however, would take a greater amount of time and would require extensive research of a classified data base to find or derive the correct values. Both would have to be tested during game play to see if results were satisfactory.

B. PROPOSED PL/I CODE CHANGES

The Game Director implemented changes can be done quickly and at little or no cost to the Navy. Coding changes will be more costly and may degrade the response time of the ENWGS.

1. Seeker Patterns

All missiles have a circular seeker pattern in the targeting model. Many cruise missile's seeker patterns adequately fit this model. The alternative to adjusting seeker turn-on ranges would be to separate air, surface, and subsurface launched cruise missile attacks from air-to-surface attacks in general. Each missile, instead of going through the present targeting routine, would call up a seeker geometry entered in the missile's preset parameters and the geometry would be centered at the target zone center. Potential targets would then be tested to see if they fell inside the seeker geometry. Another method for improving realism would be to make each missile a separate track. This would probably be too CPU-intensive and slow down the game's response time.

Another alternative would be to modify the present routine so that the seeker field of view radius was called from the cruise missile's parameters. This would eliminate testing the field of view against target zone radius, and the test to ensure that the radius was greater than 0.5 nautical miles. It would also eliminate the computation of the radius. This would save some logical lines of code and replace them with one data entry.

2. Heat Seeking Cruise Missiles

A test should be added to the targeting routine to see if the missile is a heat seeking missile. The only routine to be added would be one which assigned weights to the targets based on their heat signatures. This would be identical to the present target weighting routine except that instead of target value or radar cross-section, the value for the target IR signature would be used. The values for IR signatures are already present in the data base to support the detection models for IR sensors. In addition to changes in the targeting routine, the Battle Damage Assessment (BDA) routine could be changed. The BDA routine presently selects different portions of a platform to attack based on the angle of attack of the missile or whether the missile is an ARM. ARM missiles and high angle of attack missiles are assigned to attack the superstructure of the target. Standard missiles are assigned to hit the sides of the target. A test could be added to the BDA routine so that heat seeking missile hits would be assigned to flight decks and compartments with exhaust stacks.

3. Chaff and Decoys

The PL/I code for the release 2 version of the ENWGS still contains the lines of code to model chaff and decoys. To reinstate the chaff and decoy model used previously, these lines of code need to be reactivated. As stated earlier, the model for chaff and decoys is identical to the jamming model. The end result would be different, however. If jamming chaff or decoys were activated in the target area, the ECM value would be used to degrade the missiles performance, if it was susceptible. Also if the missile could counter jamming, chaff, or decoys, the ECCM value would be used. The flaw in this routine is obvious. If jamming and chaff are present but the missile can counter only chaff its performance is effected as if it could counter jamming. As a preliminary, the old chaff and decoy model should be reactivated. The next step is to rewrite subroutine M30.

Subroutine M30 could be rewritten to call ECM-ECCM values for each type of countermeasure. Instead of using the computation $(1 - ((1 - ECMf) \times ECMf))$, each missile should have one factor in its parameters which would represent the performance of the cruise missile if chaff, jamming, or decoys were present. For example if chaff was launched by the target, the missile's chaff factor would be called. If not, the value would be set to one, indicating no effect. Once the model had tested for all types of countermeasures, the factors would be multiplied together to produce one ECM-ECCM factor. The missile parameter table for ECM and the one for ECCM would be replaced with one table listing the effects of each countermeasure. Subroutine M30 would consist only of a group of tests to indicate if chaff, jamming or decoys were present and call up the appropriate data values. This model would show the interaction between jamming, chaff, and decoys as a multiplicative degradation in missile performance. This may or may not be realistic, depending on the missile, but it would be a step toward greater realism. Again the values could be adjusted to emphasize the accuracy of either the single countermeasure environment or the multiple countermeasure environment.

C. SUMMARY

The greatest improvement in the realism of the models can be made by rewriting the field of view determination portion of the targeting subroutine M19 and the electronic warfare subroutine M30. The recommended changes would require more memory but less computation, therefore the reaction time of the game should not change if the changes are moderate. Adjusting the data base values in the release 2 version could improve model performance quickly, however, it would initially be a burden on the naval and civilian personnel providing game support. Additionally the modification of the data

base would have to be standardized between all the facilities using the game. ENWGS release 2 models modern naval cruise missile engagements adequately. However, if the data base could be better related to the models it is used in, the realism of the game could be improved. Currently the models for cruise missile engagements are adequate but lack the flexibility to recreate the capabilities and variety of modern cruise missiles.

APPENDIX FLOW CHARTS

The flow charts on the following pages were derived directly from the PL/I code for the subroutines being described.

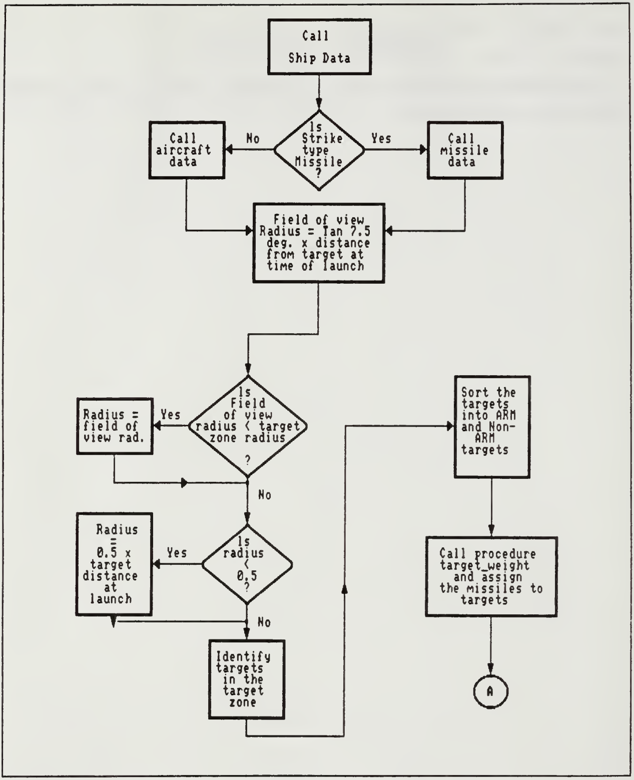

Figure 1. Figure 1. Air-to-Surface Targeting, subroutine M19

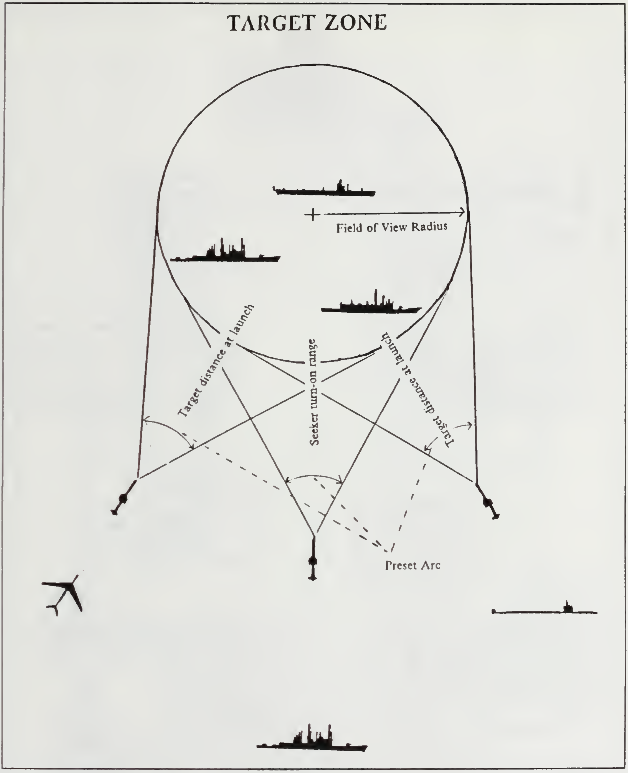

Figure 2. Figure 2. Target Zone example

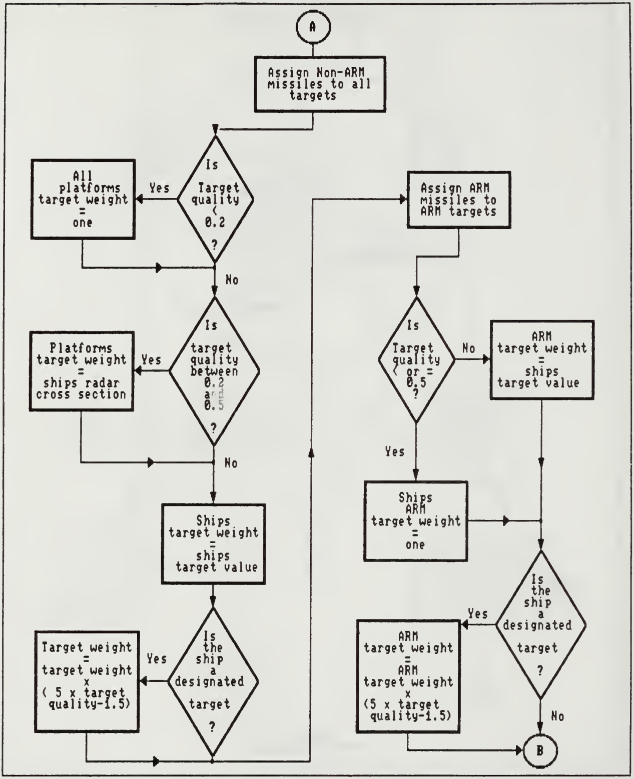

Figure 3. Figure 3. Procedure Target_Weight

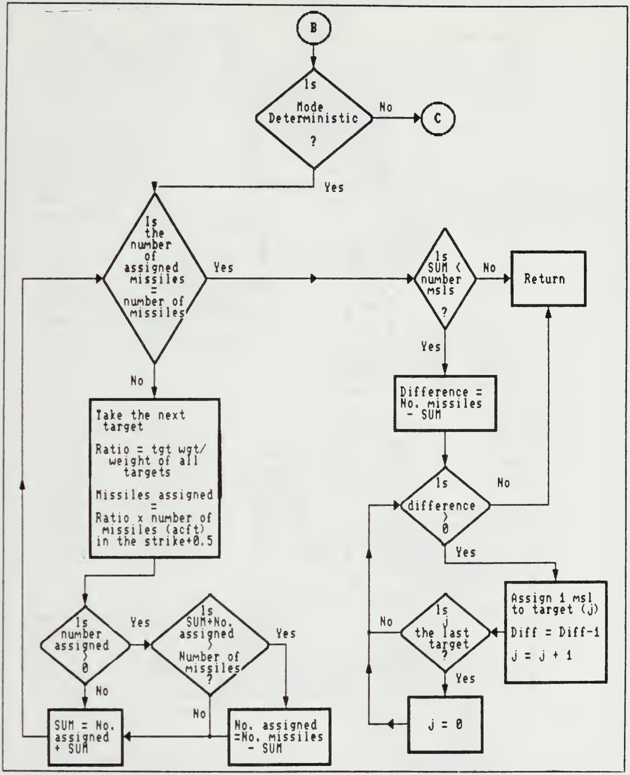

Figure 4. Figure 4. Air-to-Surface Targeting, subroutine M19 (continued)

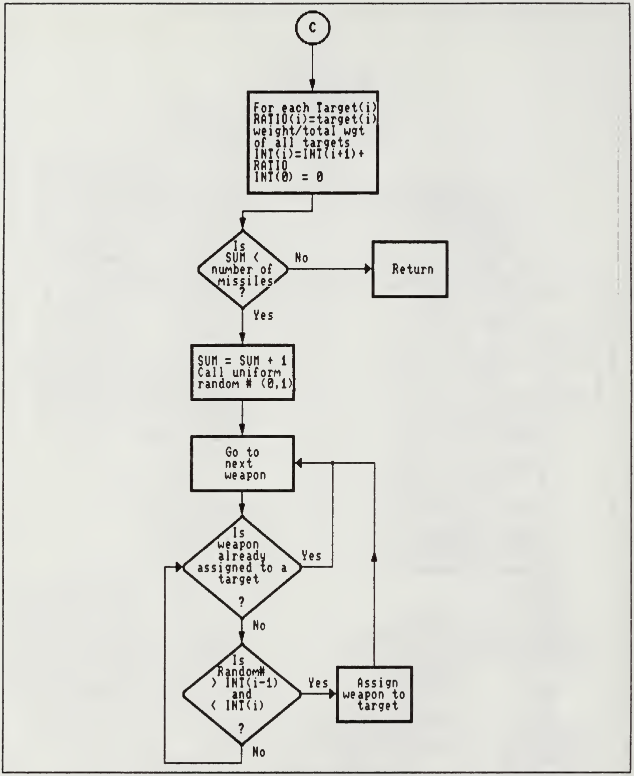

Figure 5. Figure 5. Air-to-Surface Targeting, subroutine M19 (continued)

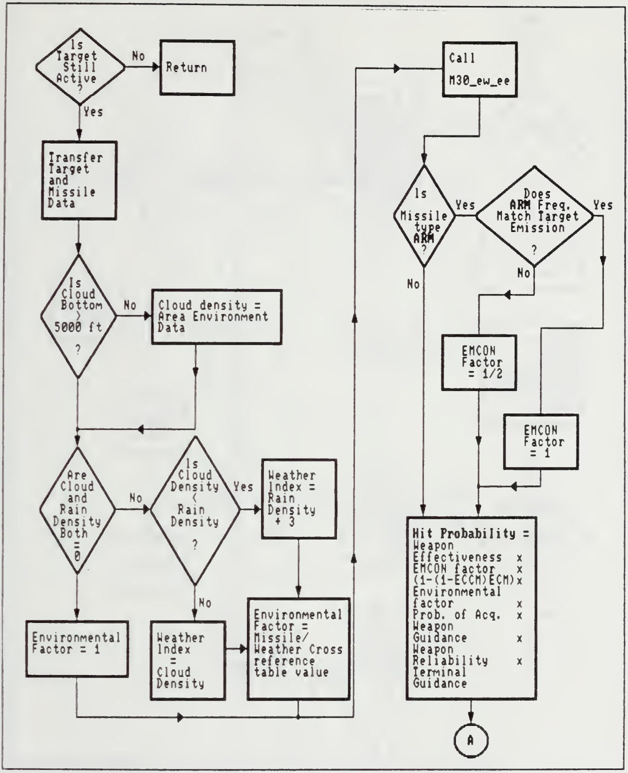

Figure 6. Figure 6. Hit Determination, subroutine M22

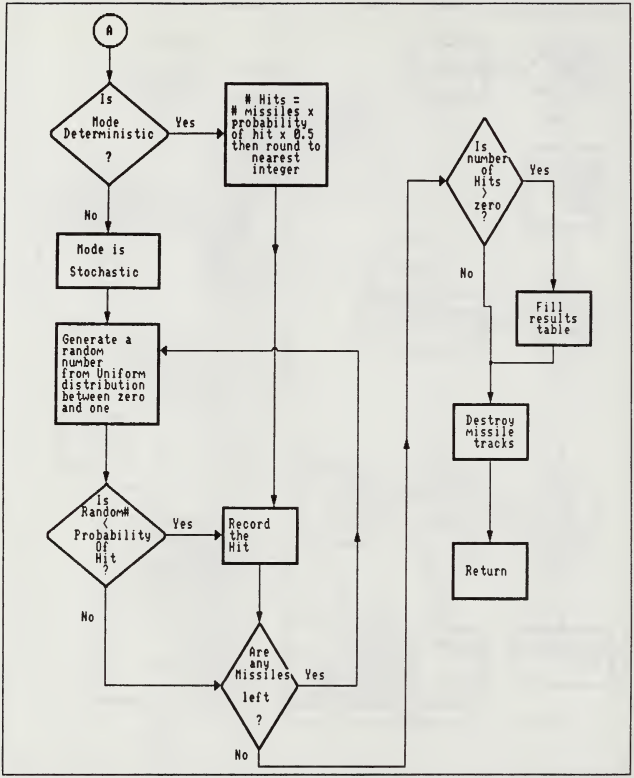

Figure 7. Figure 7. Hit Determination, subroutine M22 (continued)

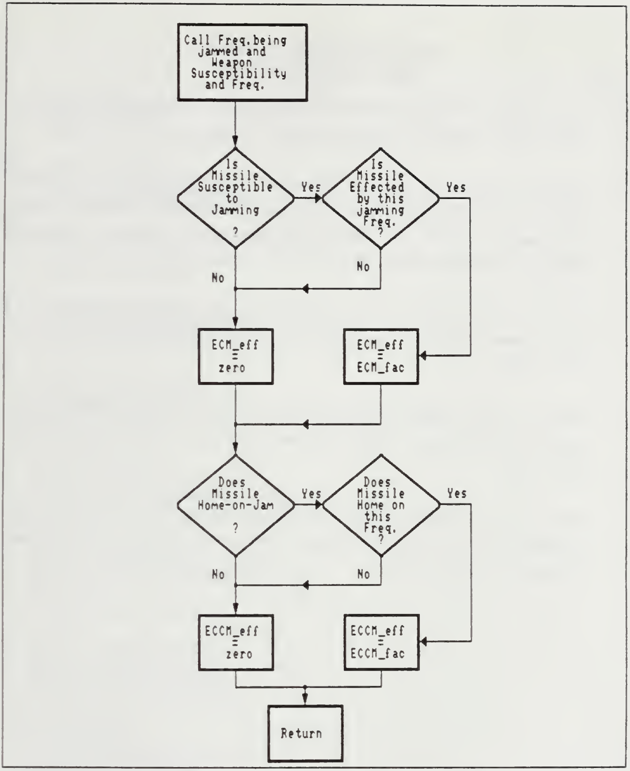

Figure 8. Figure 8. Electronic Countermeasures, subroutine M30

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